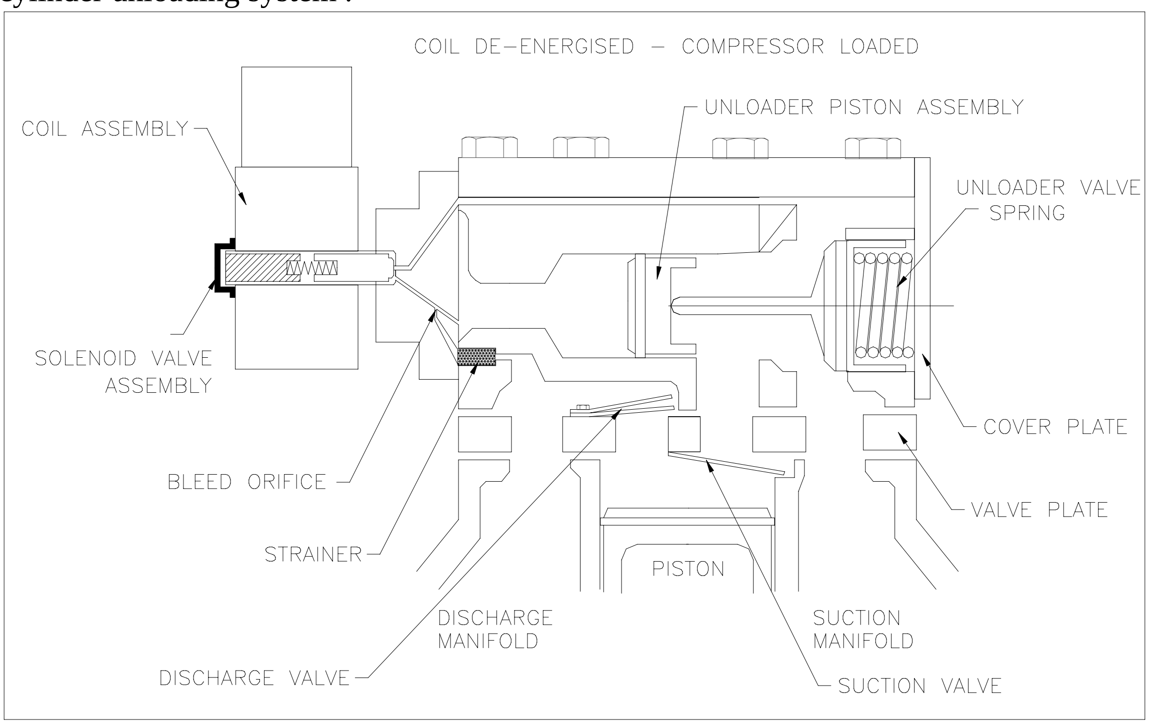
Fundamentals of Refrigeration Part 4 Refrigeration 3.

Capacity control on cooling side.

As we have discovered, a reduction in heating load on the evaporator causes the system to rebalance at a different operating point. This may not be acceptable for a number of reasons. The evaporating temperature may go below zero which could cause the evaporator to frost up . The air temperature leaving the coil can also be drastically reduced which would cause blasts of cold air to be directed at the occupants of an air conditioned building. We must therefore find a way to reduce the refrigeration effect of the equipment.

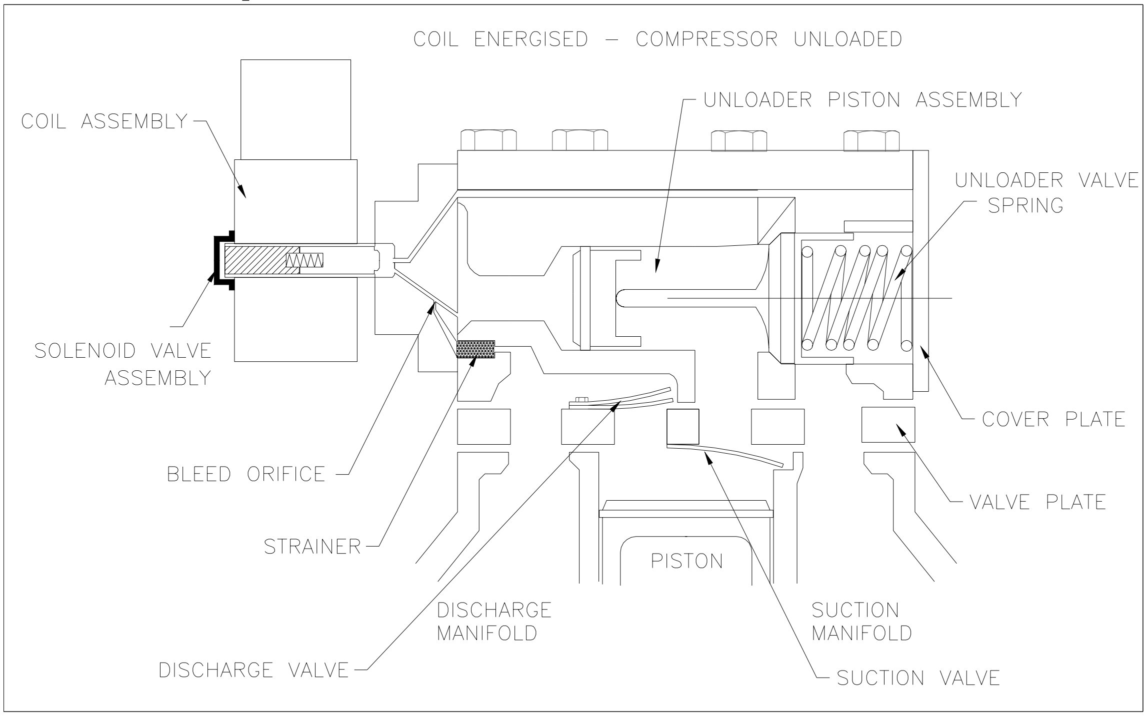
The simplest method is to switch off the compressor. This would be used on systems having multiple refrigeration sections or a single section evaporator connected to a compressor pack with more than one compressor.

Where there is a single compressor with multiple cylinder heads it is common to have a cylinder unloading system .



This method reduces the swept volume by preventing the refrigerant from entering the cylinder head . This diagram shows the arrangement when the solenoid coil is de-energised and the compressor is fully loaded. The solenoid valve is closed ,which prevents refrigerant from flowing down the channel to the suction side of the system. Refrigerant gas at discharge pressure enters the chamber behind the unloader piston and pushes the piston against the spring. The spring is compressed and the gas flows through the valve to the suction side of the valve plate.

This diagram shows the same compressor once the solenoid valve has been energised. The valve is now open .

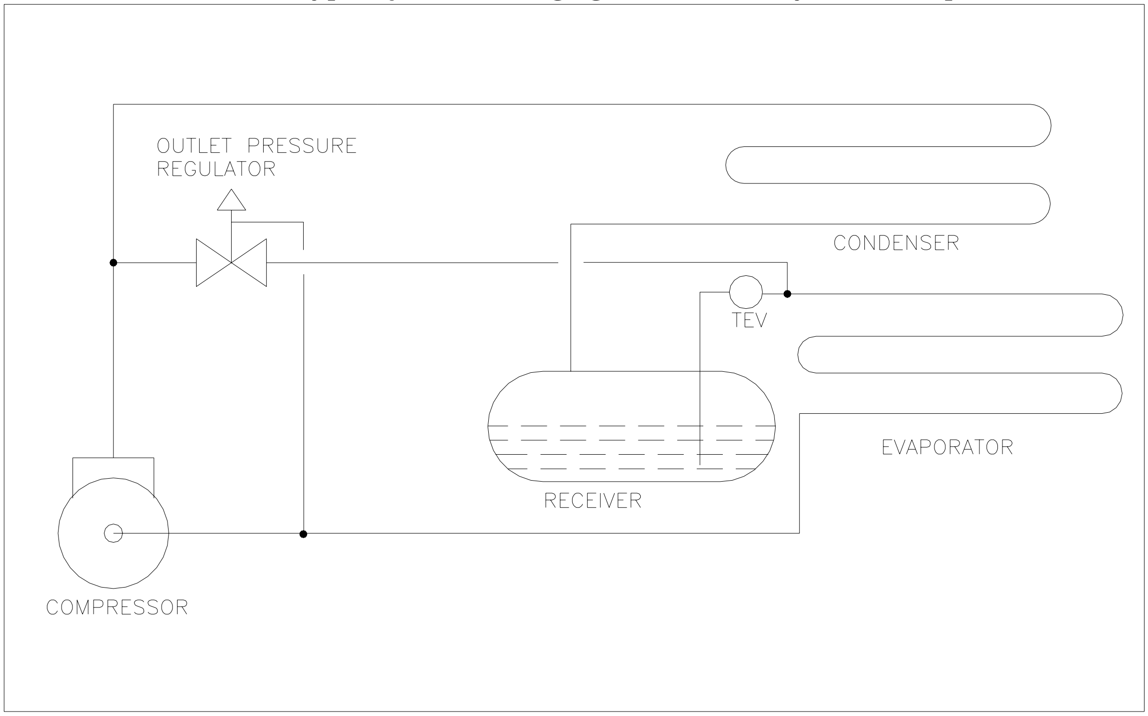


This lets gas from the chamber behind the unloader piston to bleed to suction pressure. The spring pressure is now sufficiently high to move the piston against the pressure in the chamber behind the piston which lets the valve close. Once the valve has closed no gas can reach the suction side of the valve plate and no compression takes place

The main drawback to this system is that the drive motor operates at a less efficient point with a consequent penalty in the operating efficiency.

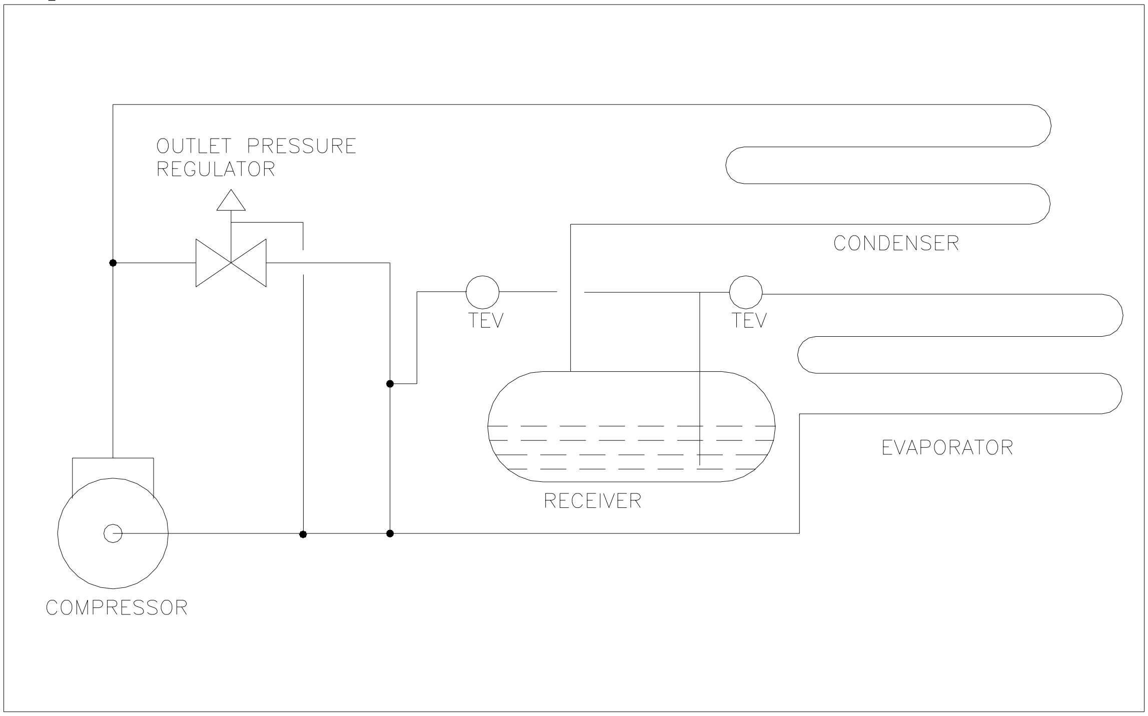
A third method involves the use of speed control of the compressor drive motor. This is more efficient than the use of cylinder unloading but has the following operational limitations. Larger compressors are all fitted with a mechanical oil pump which is driven from the main drive shaft. It therefore follows that any reduction in the speed of the drive motor will slow down the oil pump. The pressure developed by a pump is proportional to the square of its speed whereas the pressure drop for a given flow of oil through the compressor oilways is a fixed level. This means that the oil pump must be capable of supplying the minimum oil quantity against a fixed pressure drop at the minimum speed envisaged for operation of the compressor. Another major drawback is the cost of large capacity speed controls which may cost considerably more than the compressor it is controlling.

The final method of control that I want to discuss is hot gas injection. This is a method of capacity control which is relatively inexpensive and simple. There are two types in common use . The first type injects discharge gas into the entry of the evaporator.



This does two things, firstly it put a quantity of heat into the coil which will assist in boiling off the liquid refrigerant present. The second thing that happens is that a quantity of vapour from the compressor forms a part of the total vapour drawn back to the compressor and therefore has the effect of reducing the mass flow of refrigerant being circulated. This type is most frequently used where the evaporator is close to the compressor or condenser.

The second type injects the hot gas in the suction line of the compressor reducing the swept volume as described above.



It does not introduce any heat into the evaporator. With this type of control it is usual for a liquid injection valve to be fitted which will cool the discharge gas before it is returned to the compressor.

Head Pressure Control

Air cooled condensers are always selected to reject the required heat at maximum predicted operating ambient temperatures. This means that for the majority of the operating life of any machine it will be operating at less than maximum capacity.

The duty obtained from one or more compressors will be determined by a combination of the saturated suction temperature and the saturated discharge temperature; in general terms the smaller the difference between the condensing and evaporating temperatures ,the greater duty will be obtained. This would suggest that it would be a good thing to let the discharge pressure float down to as low a point as possible to reap the benefit of this. There is, however, a complication with this view in that the expansion devices require a certain pressure differential in order to operate correctly and for that reason it is necessary to control the extent to which the discharge pressure is allowed to fall.

Control theory

Essentially the ability of the air cooled condenser to reject heat is determined by its geometry (number of rows, face area, fin spacing etc.), the quantity of air blowing across the coils and the difference between the ambient temperature and the condensing temperature. If we are to attempt to maintain the condensing condition and we accept that we are unable to control the ambient temperature there are two basic strategies which can be employed. Strategy 1 is the control of the volume of air which is passing over the coils, Strategy 2 is the reduction of the coil surface which is available for condensing refrigerant.

Strategy 1 control options

There are three main methods employed under strategy 1 to reduce the airflow passing over the coils. The most common method is cycling of the fans. The fans would progressively be brought on line in response to increasing discharge pressures which are sensed by pressure switches or a transducer. The success of this method is dependant on there being sufficient numbers of fans to give a small pressure response to the enabling or disabling of one or more fans and the limits of operation of the condenser which will be acceptable for the operation of the refrigeration equipment. Disadvantages of this method of control are usually associated with pressure differentials which have been set too low on the pressure switches causing the fans to hunt.

An alternative to cycling of the fans is to control the running speed of the fans to regulate the airflow. This has three distinct advantages over fan cycling, firstly it is infinitely variable and it is not so critical to have a large number of fans, secondly the proportional operating band can be quite small as you are not trying to match steps and thirdly the reduction in speed has a significant effect in reducing noise levels (particularly at night when ambient temperatures tend to be lower) .The most common method to achieve this is by fitting a frequency inverter to drive all the fans in response to a pressure signal.

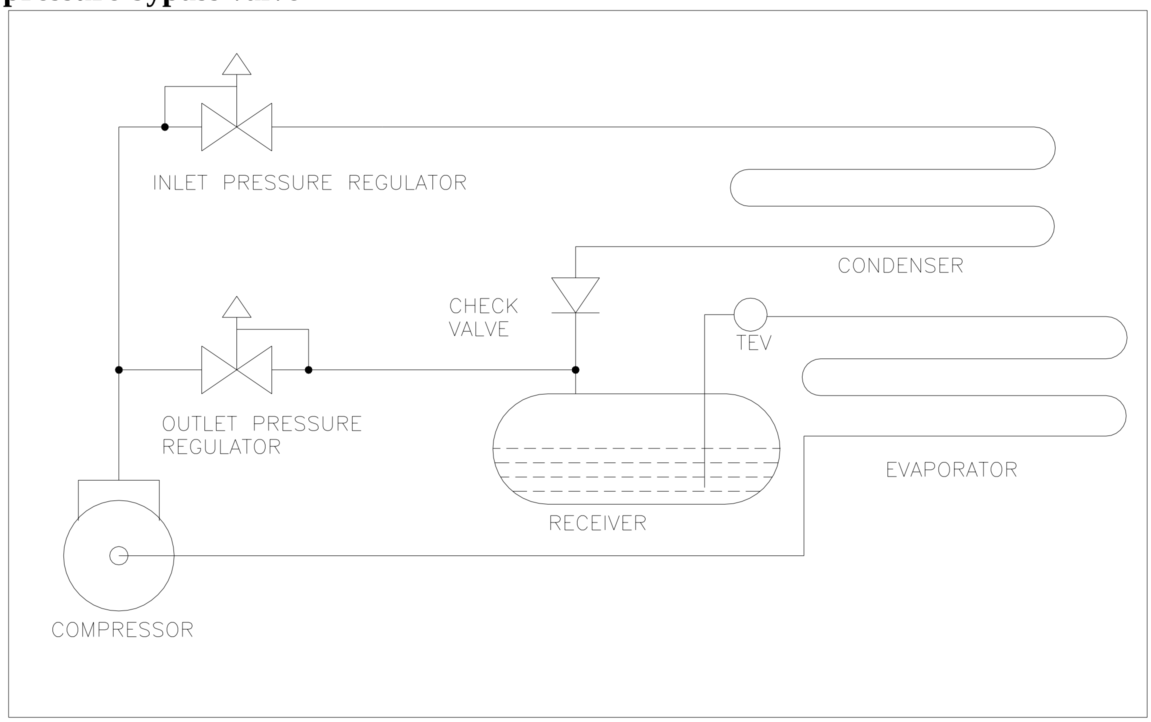
The disadvantages associated with speed control tend to be related to high initial costs and the possibility of an inverter trip which would disable the equipment completely.

The third method ,which is rarely seen these days, is to allow air to bypass the coil using motorised dampers connected to a neutral zone pressure switch thereby reducing the amount of air which passes over the coil.

Strategy 2 control options

For strategy 2 it is necessary to reduce the coil surface which is available to condense refrigerant. There is really only one way in which this can be achieved and that is by flooding the coil with liquid refrigerant. As the full surface will be required when we reach peak ambient temperatures it is always necessary to have a liquid receiver large enough to carry the operating charge of the system in addition to the quantity of liquid necessary to flood the coil to the required level Flooding the condenser coil is achieved using mechanical valves to restrict the flow of refrigerant through the condenser there are ,however , two ways in which this is accomplished.

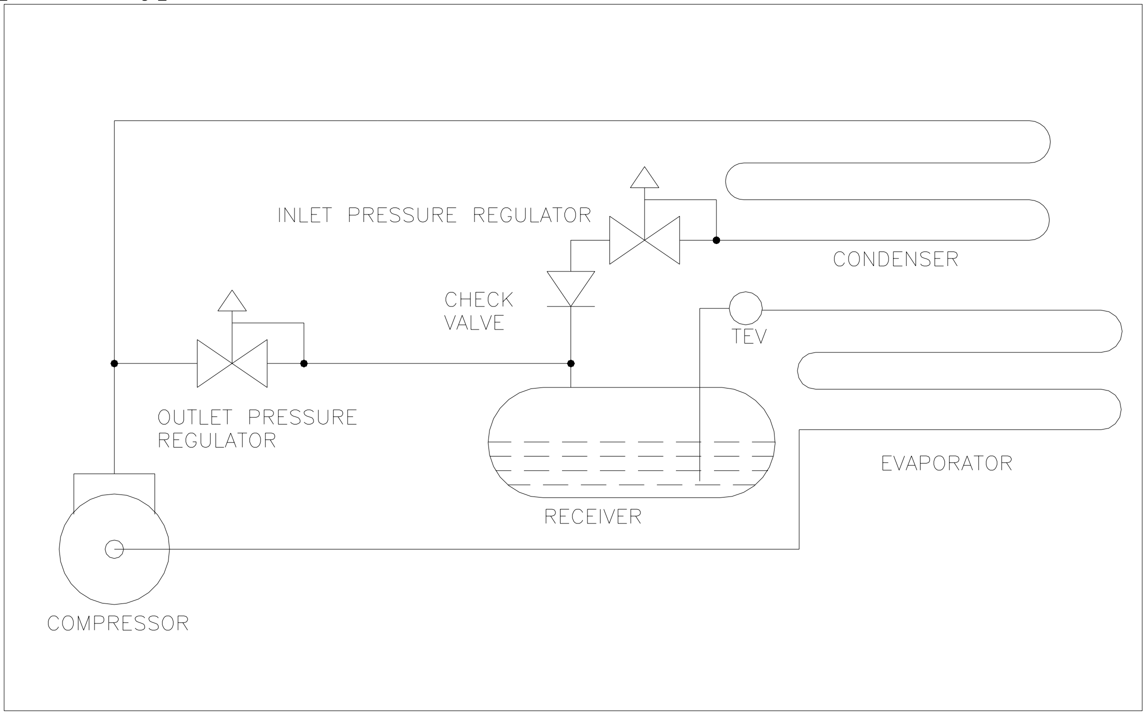
Method 1 inlet pressure regulator on the entry to the condenser and differential pressure bypass valve



This method consists of an inlet pressure regulator which controls the pressure of the gas which is being supplied by the compressor by throttling the gas which is entering the condenser. A differential bypass valve is fitted between the discharge line upstream of the inlet pressure regulator and the liquid receiver. This valve maintains the receiver pressure at a point where the liquid refrigerant has sufficient pressure to supply it to the system.

When the inlet pressure regulator closes down to maintain the upstream pressure, the liquid refrigerant is not able to leave the condenser and so starts to fill the tubes. When the tubes have filled to a level where the condenser is only capable of condensing at a discharge pressure greater than that set on the valve, the inlet pressure regulator will begin to open and a quantity of liquid refrigerant will leave the condenser. The condenser will remain in its flooded condition until the discharge pressure begins to rise , at which point the inlet pressure regulator will open further and permit more refrigerant to leave the condenser.

Method 2 inlet pressure regulator on the outlet of the condenser and differential pressure bypass valve



This method uses an inlet pressure regulator fitted to the outlet of the condenser. The method of operation varies from that previously described in that all the refrigerant (other than that required to maintain the receiver pressure) passes into the condenser. The inlet pressure regulator will only permit refrigerant at a pressure greater than its setpoint to leave the condenser. After a period of time the condenser will flood to a point where the refrigerant pressure exceeds the setpoint on the pressure regulator and it is allowed to leave the condenser. The main difference between the operation of the two systems is that the latter method will take a time to build the discharge pressure to the required level whilst the first method will control the discharge pressure very quickly.

Advantages associated with this method of control are listed below.

1. Very accurate and stable control can be achieved
2. Multi circuited condensers can be provided with a single set of fans
3. A level of subcooling will result and improve the overall operating performance of the refrigeration system

Disadvantages associated with this method of control are listed below.

1. Fans run continuously
2. Additional refrigerant charge is required to enable coils to flood

Combination methods

In order to take advantage of the benefits of the various methods of head pressure control it is quite common for combinations of the two strategies to be used.

A common method is to employ a combination of fan cycling and liquid flooding. When the fans cycle off the condenser does not need to be flooded to the same level to achieve good control.

Setting of the valves and pressure switches is very important when this method is used as the liquid back up will tend to keep the fans in operation by preventing the pressure from falling below the differential pressure on the enabling pressure switches. Some systems operate with a strategy that will switch fans off periodically in order to determine whether they are needed.

Speed controls may also be combined with liquid flooding but this is only normally used on multicircuited condensers requiring very accurate head pressure control on all systems.